Displacement and Velocity

Frames of Reference

Let's say I am standing on the back of a pickup truck that is motionless and I am throwing apples forward. I know that I can throw an apple at exactly 15 m/s every time. If a person were standing on the sidewalk, how fast would she say the apples are moving?

Now the truck starts moving forwards at 20 m/s. I am still throwing apples forwards, exactly the same as I was throwing them before, at 15 m/s. How fast would the spectator say the apples are moving?

How fast according to me does it look like the apples are moving?

When you are standing on the ground, that is your frame of reference. Anything that you see, watch, or measure will be compared to the reference point of the ground. If I am standing in the back of the moving truck, the truck is now my frame of reference and everything will be measured compared to it. We say that moving objects have relative velocity.

Sitting at your desk, how fast are you moving relative to the ground? Relative to the sun? Which answer is correct?

We show different motions as arrows in the direction objects are moving. We call these vectors.

Vectors

While motion can be described with words, that is often not good enough. Physics is a mathematical science, so we use two categories of mathematical quantities to describe motion:

Scalars

-quantities described with a magnitude (or number) only

-Ex. Temperature, mass, and speed

Vectors

-quantities described with both magnitude and direction

-Ex. Velocity, force, acceleration, displacement, weight, momentum

Ex. Which of these is a scalar? A vector?

8 m	26.4 m/s East	84°C	52.0 m/s	3 km [N]

Drawing Vectors to Scale

Vectors are used to represent vector quantities on a diagram. A vector is composed of a line segment drawn to scale with an arrowhead at one end. The tail of the vector is at its origin and the head is at the terminal point (the arrowhead). The length of the vector represents its magnitude and the arrowhead indicates its direction. When drawing vectors you must also include reference coordinates. Notice that the direction is given inside square brackets.

Ex. Draw 24 km [E] to scale

Ex. 57m [N]

Ex. Draw 60 m [S27°E]

60 m [S27°E] could also be represent by 60 m [27° E of S] or 60 m [297°]. When using the cardinal directions, your angle should be less than 90°.

Collinear vectors are vectors that exist in the same dimension. In other words, they exist either in the same direction or in the opposite direction. Non-collinear vectors are vectors that exist in more than one dimension (i.e. they are located along different straight lines).

Position

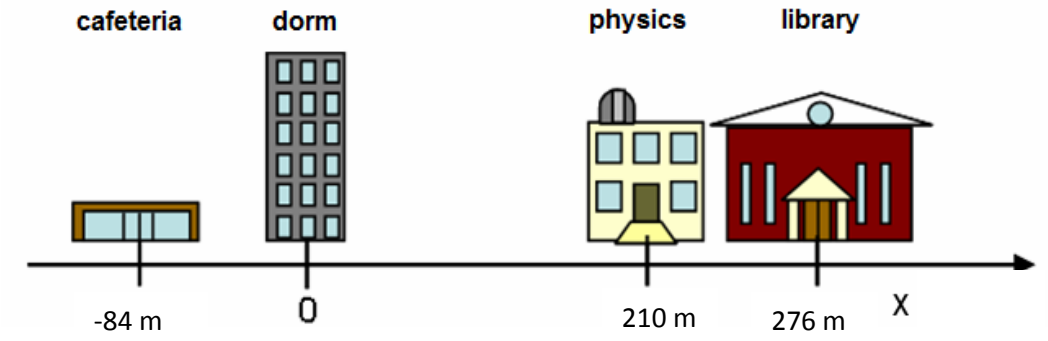
Position is the separation and direction from a reference point. It involves both the straight-line distance and direction from the reference point. Usually, the reference point is the origin or starting point. You need to decide which directions will be positive, and which directions are to be negative.

Symbolically, position is shown as $\vec{d}$. Note the arrow to show that it is a vector quantity.

Displacement is your change in position. Symbolically,

$\Delta\vec{d} = \vec{d}_2 - \vec{d}_1$	Where $\Delta\vec{d}$ = displacement $\vec{d}_2$ = second position $\vec{d}_1$ = first position

Ex.



Ex. What is your displacement going from the cafeteria to the physics building?

Ex. What is your displacement moving from the library to the physics building?

Adding Vectors Along a Straight Line

Using a scale diagram:

1) State the directions
2) List the givens and indicate what variable is being solved
3) State the scale to be used (ex. 1 cm = 5 m)
4) Draw one of the initial vectors to scale
5) Join the second and additional vectors head to tail and to scale
6) Draw and label the resultant vector
7) Measure resultant vector and convert the length using your scale
8) Write a statement including both the size and direction of the resultant vector

Ex. 45 km [N] + 25 km[N] + 35 km [S]

Ex. John takes his dog, Slatrbartifast the Third, for a walk. They walk 310 m [W] and then back 225 m [E]. Draw a vector diagram to find their resultant displacement.

Adding vectors algebraically:

To add vectors algebraically, you again have to assign a positive or negative direction to the quantity. At the end of the calculation, you must translate the positive and negative back into a direction.

1) Indicate which direction is positive and which is negative
2) List the givens and indicate what variable is being solved
3) Write the equation for adding the vectors
4) Substitute numbers (with correct signs) into the equation and solve
5) Write a statement with your answer including size and direction

Ex. Slartbartifast the Third decides to take himself for a walk. He heads 478 km [W], stops, and then goes a further 84 km [W] before returning 243 m [E]. What is his resultant displacement?

Adding Vectors at an Angle

This is essentially the same as before, but now the vectors are not all in a line.

1) Use a sharp pencil, ruler and protractor
2) Choose and state a scale that fits your page or space available
3) Calculate the length, to scale, of each of your vectors
4) Draw the compass symbol on your page, with north toward the top
5) Draw the first vector using your ruler and protractor
6) Draw the second vector with its tail at the head of the first
7) Continue adding as many vectors as necessary, always placing the tial of the next vector at the head of the previous arrow
8) Draw the resultant displacement as an arrow from the tail of the first vector (the initial position) to the head of the last vector (the final position)
9) Use your protractor to find its angle from a compass direction and your ruler to measure its length
10) Using your scale, convert the measured length to the actual resultant displacement
11) State the resultant displacement, including size and direction

Ex. Sally walks to Sue's home by going one block west and then two blocks north. Each block is 160 m long. What is Denise's final displacement?

Ex. 4.2 m/s [N37°W] + 2.1 m/s [S15°E]

Velocity

Velocity is essentially speed along with a direction. Constant velocity means both your speed and direction stay the same.

Average velocity is the overall rate of change of position from start to finish.

$$\vec{V}_{av} = \frac{\Delta \vec{d}}{\Delta t}$$

Where $\Delta \vec{d} = \vec{d}_2 - \vec{d}_1$
$\Delta t = t_2 - t_1$
$\vec{v}_{av}$ = average velocity

The direction of your average velocity will be in the same direction as the displacement.

Ex. A jogger runs 76 m [E] in 10.0 s and then 51 m [W] for 8.0 s,

a) What is the jogger's velocity for the east portion?

b) What is the jogger's velocity for the west portion?

c) What is the jogger's average velocity for the entire run?

d) What is the jogger's average speed for the entire run?